

THE EASTERN MUDSNAIL, *ILYANASSA OBSOLETA*, ACTIVELY FORAGES FOR,
CONSUMES, AND DIGESTS CYSTS OF THE DINOFLAGELLATE,
SCRIPPSIELLA LACHRYMOSA

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ABSTRACT

The Eastern mudsnail, *Ilyanassa obsoleta*, was attracted to, consumed, and digested resting cysts of the dinoflagellate *Scrippsiella lachrymosa* when cysts were presented in grazing experiments. Twenty snails were observed individually for one hour in petri dishes divided into four parts wherein cysts were present in one quadrant, sediment particles of the same size range were in another quadrant, and two quadrants were free of particles. Actively foraging snails were nearly twice as likely to be found in quadrants containing *S. lachrymosa* cysts as in the other quadrants until cysts were consumed. Microscope observations of fecal pellets from snails feeding on cysts revealed digestive destruction of the cysts. These findings indicate that deposit-feeding grazers can actively seek dinoflagellate cysts as a food item, thereby influencing distribution of cysts and subsequent germination of dinoflagellate vegetative cells.

Key words: deposit feeding, dinoflagellate resting stages, cyst ecology.

INTRODUCTION

Dinoflagellate cysts have, until recently, been largely regarded as inert particles, unaffected by processes other than sedimentation and accumulation. However, evidence is accumulating that many different animals ingest and digest, or at least destroy, dinoflagellate cysts when they are grazing (Persson & Rosenberg, 2003). Cysts are frequently found in the fecal pellets of deposit feeders (Persson & Rosenberg, 2003; Kremp et al., 2003), copepods (Reid & Boalch, 1987), and filtering bivalves (Bravo et al., 1998, and references therein). Cysts are known to contain lipid and starch (Dale, 1983), and therefore could constitute a source of nutrition for grazers, but it is unclear if the cysts are eaten indiscriminately or if they are actively sought. In this experiment, we used the eastern mudsnail, *Ilyanassa obsoleta*, as a model deposit-feeding grazer to determine if cysts attract active grazing by a foraging, surface-deposit feeder. The cysts used were produced by pure cultures of *Scrippsiella lachrymosa*.

MATERIALS AND METHODS

The strain of *Scrippsiella lachrymosa* (strain B10) used was kindly provided by Anke Kremp, Woods Hole Oceanographic Institution. Cultures were grown in f/10-enriched Milford Harbor seawater (a variation of f/2; Guillard & Ryther, 1962) with 5% sediment extract, and encystment was induced by transfer to f/2 without nitrogen enrichment (Smith & Persson, 2004, provide details of encystment method). Cysts were sonicated 4 min (Sonicor SC-50) and rinsed thoroughly by spraying with filtered seawater on a 20 µm sieve to remove any remaining debris from the culturing medium.

The *Ilyanassa obsoleta* were collected at Fort Trumbull Beach, Milford, Connecticut, USA, from the intertidal zone on December 31, 2002, and kept in running seawater until the start of the experiment 17 days later.

The experimental containers are shown in Figure 1. Twenty, 90 mm glass petri dishes, marked with a pencil on the outside of the bottom into four equal quadrants, were placed on a table, at room temperature, and filled with

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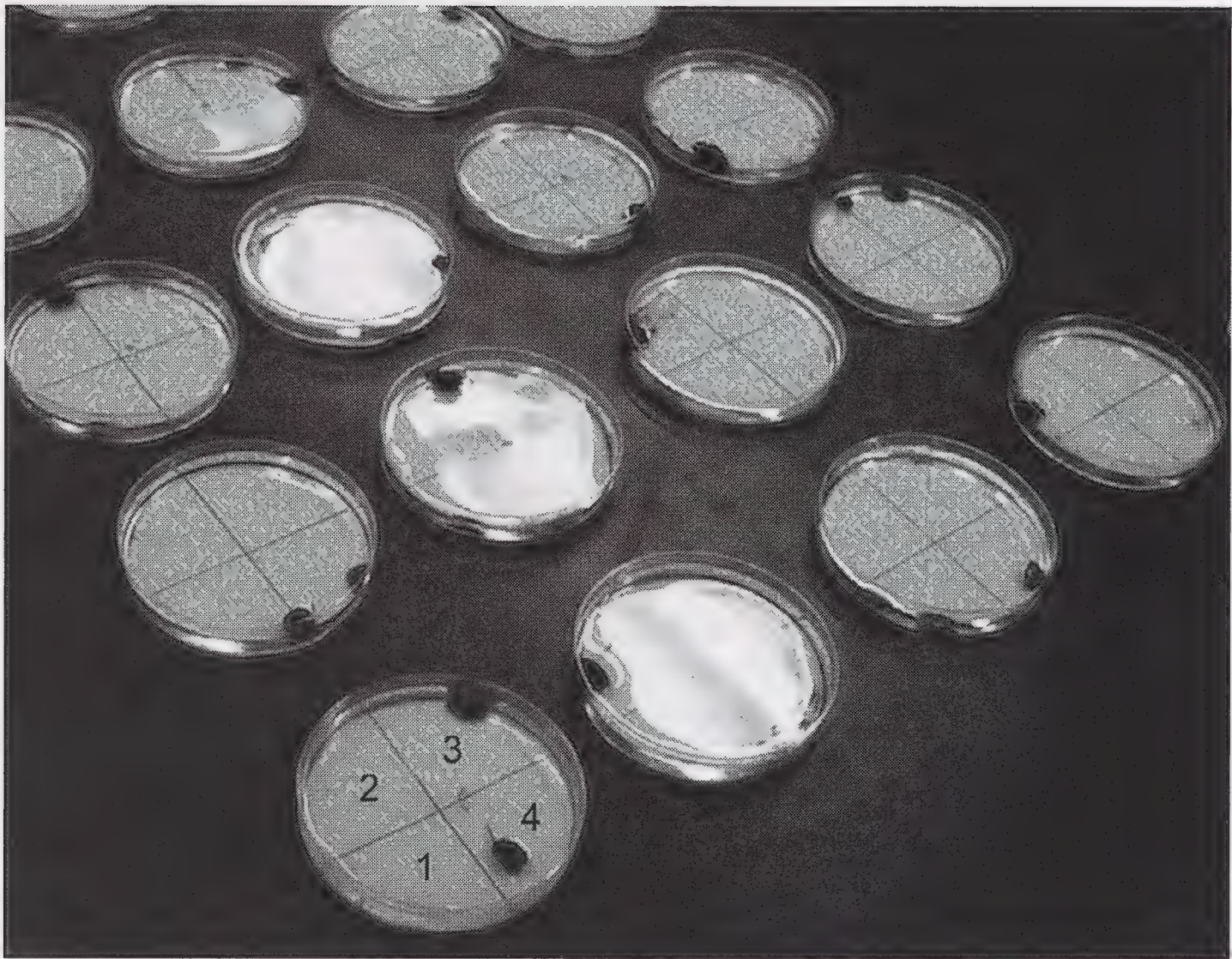


FIG. 1. Petri dish divided into quadrants with (1) cysts of the dinoflagellate, *Scrippsiella lachrymosa*, (2) no particles, (3) sediment 20–100 μm , and (4) no particles, used for selection experiment with Eastern mud snails, *Ilyanassa obsoleta*.

40 ml filtered seawater. In one quadrant of the dish, *Scrippsiella lachrymosa* cysts were placed (~800 cysts/dish), in the quadrant diagonal to the cysts, sieved sediment particles from Fort Trumbull Beach of the same size range (20–

100 μm) were placed. The other two quadrants of the dish were left empty of particles. Petri dishes were oriented haphazardly so that possible, unknown factors of orientation in the room would not influence the results.

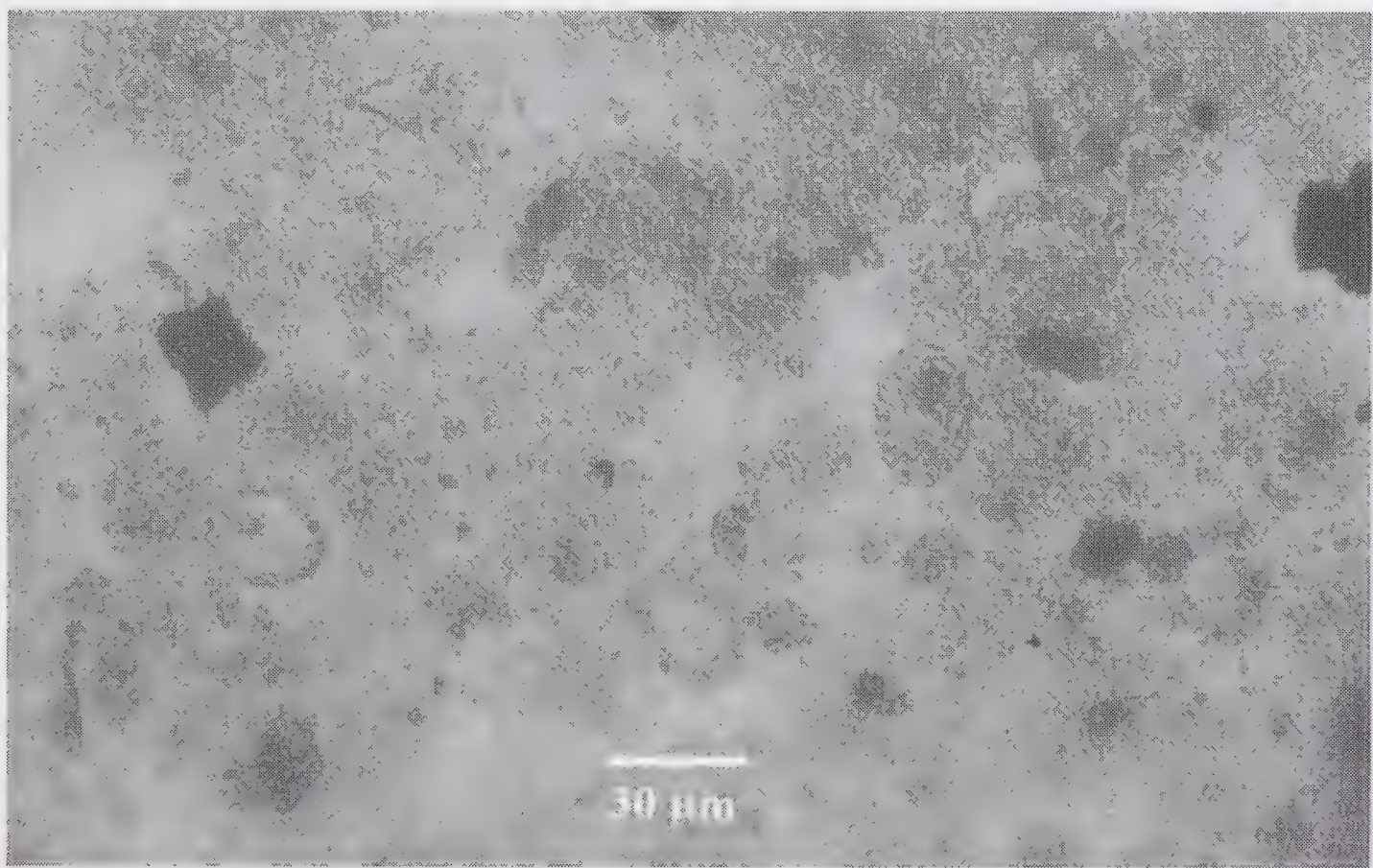


FIG. 2. Photomicrograph of fecal pellet from an Eastern mud snail, *Ilyanassa obsoleta*, that had fed on cysts of the dinoflagellate, *Scrippsiella lachrymosa*. Partially and fully degraded material from cysts is present, indicating digestive degradation of the cysts.

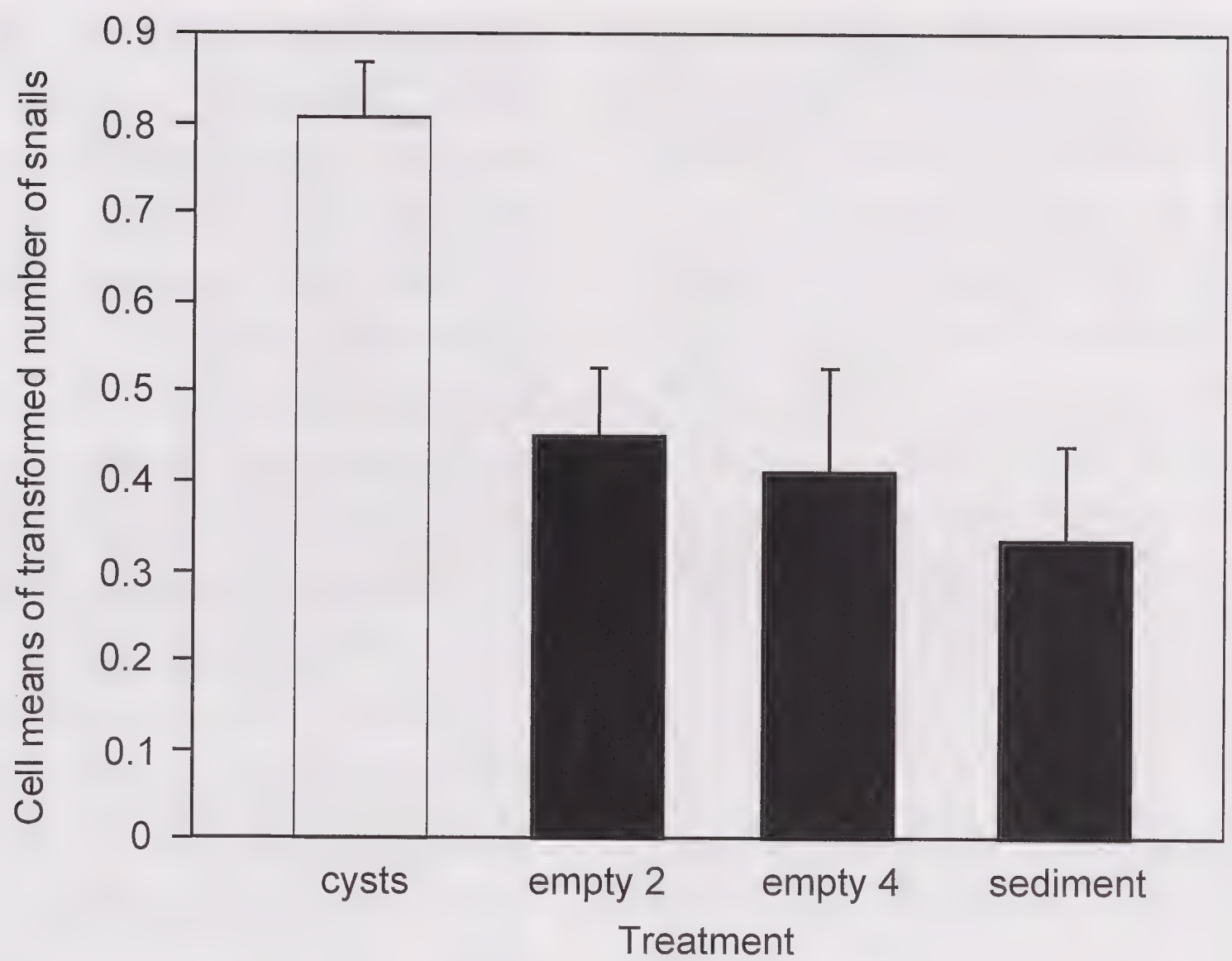


FIG. 3. Mean ($\pm$ SD) transformed percentages of snails found in experimental quadrants over 65 min of sampling at 5-min intervals.

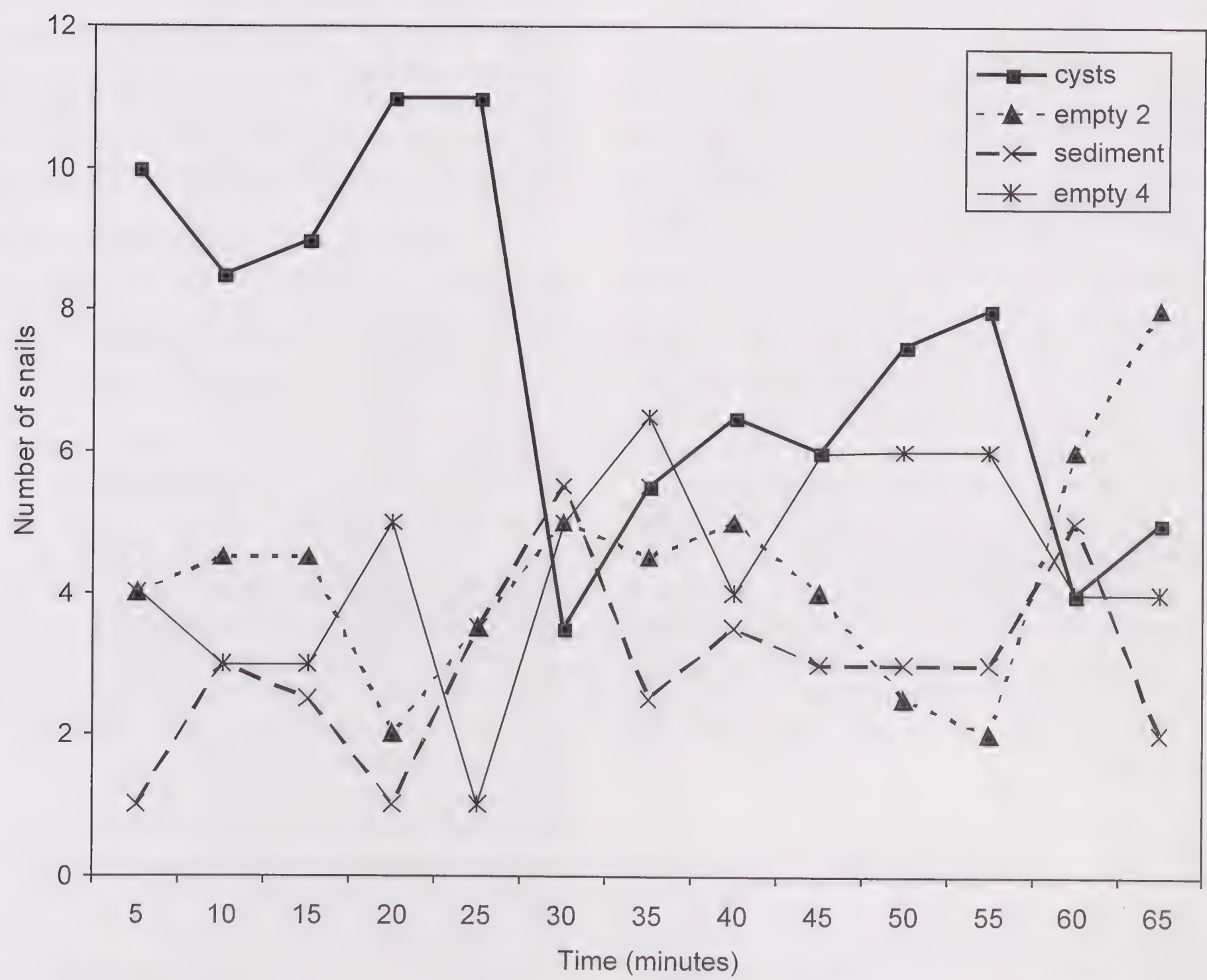


FIG. 4. Numbers of snails found in each experimental quadrant at each sampling time.

At start of the selection experiment, one snail that had been starved previously was placed in the center of each petri dish. Thereafter, all snails were observed continuously, and notes were made on which quadrant they were in every five min for 65 min. The experimental procedure was first tested with a diatom, *Amphora* sp., as a food source to verify effectiveness of the method. Snails moved randomly until encountering the diatom quadrant and then remained until cells were consumed. Quantitative data for the *S. lachrymosa* selection experiment were recorded as percentages of snails in each quadrant at each time. Analysis of variance was conducted on transformed ($x' = \arcsin\sqrt{x}$) values according to Underwood (1997).

Preliminary, qualitative grazing studies had shown that this snail species fed on *S. lachrymosa* cysts when they were presented in petri dishes as the only available particle. From this preliminary experiment, fecal pellets were collected by holding snails between two small, 20 μm sieves in running seawater over night after at least one hour feeding on cysts.

RESULTS

In the preliminary, qualitative grazing experiment, the majority of cysts appeared to be digested; the fecal pellets were composed of partly digested cysts that were rounded, discolored, and thin-walled without the outer layer of calcite crystals, and material that could be identified as parts of cysts (starch grains and red accumulation bodies) (Fig. 2).

In the selection experiment, snails were significantly ($p = 0.0001$) more often located in the part of the petri dish with cysts, until all cysts were consumed (Figs. 3, 4). During the 65 min observation period, snails moved randomly and continuously but, upon encountering cysts, they slowed and fed on the cysts (Fig. 4). Snails returned to the quadrant and fed repeatedly until all cysts were consumed. One snail did not move at all during the entire experiment and had to be removed from the data. Only in this petri dish were cysts not eaten at all.

DISCUSSION

The eastern mud snail cannot be said to be an important grazer on dinoflagellate cysts in nature because it inhabits the intertidal zone (Bianchi & Levinton, 1981), not a habitat where

dinoflagellate cysts typically accumulate (Dale, 1983). Nevertheless, this species does feed on microphytobenthic algae and settled phytoplankton, and actively forages for these food sources on the sediment surface. The objective of this experiment was to determine if cysts can be attractive food for foraging deposit feeders, and thus the mud snail is an appropriate test grazer. The experiment showed that snails were attracted to and consumed *Scrippsiella lachrymosa* cysts. This is in accordance with what is known for land plant seeds, which are consumed by animals and can be very important food items (Leck et al., 1989, discuss land plant seed ecology), because seeds generally contain energy stores necessary for germination and early development. It is reasonable that the same rules of ecology apply in the marine sediment as in the soil on land (Persson, 2000). Resting stages at the sea floor can be, and are subjected to grazing pressure. This can be assumed to be different for different resting stages and also for different animals feeding on the same resting stage. Kremp and co-workers (2003) fed *Scrippsiella lachrymosa* cysts (the same strain used here) to three different species of polychaete deposit feeders. They found that the cysts passed through the worms without being digested. Thus, it appears that the mud snails used in the present study have digestive capabilities more effective at degrading *S. lachrymosa* cysts than do polychaetes.

The resting cyst of the toxic (PSP-producing) dinoflagellate *Alexandrium fundyense* has a wall that is very resistant to mechanical damage, but is not resistant to acids or digestive enzymes of many animals. We observed that *A. fundyense* cysts could not be crushed by pressing them between two slides (which easily crushes other cyst species), but these cysts were digested by the eastern oyster, *Crassostrea virginica* (Persson et al., 2006). We have performed another experiment in which *A. fundyense* cysts were fed to mud snails in a qualitative, petri-dish experiment in the same manner as described here for testing digestibility of *S. lachrymosa* cysts. Microscope observations of fecal pellets revealed that *A. fundyense* cysts were destroyed in the digestive process of mud snails; the mucus layer disappeared, and empty cysts and cysts broken at one end were common in fecal pellets.

We conclude that dinoflagellate cysts can be recognized as food by foraging, deposit-feeding animals and used as a food item. This adds to the developing picture of the "seed ecol-

ogy" of dinoflagellates. Some species have thick-walled cysts and are not easily destroyed, for example *Lingulodinium polyedrum* (Persson & Rosenberg, 2003); whereas, other species are found in higher proportions in anoxic areas, for example, *Alexandrium* spp. (Lewis et al., 1979; Keafer et al., 1992). It is logical to conclude that dinoflagellate cysts in aerobic areas are subjected to more grazing pressure than those in hypoxic or anaerobic areas with fewer grazers. Thus, there is a risk that cysts of harmful dinoflagellates can accumulate more if there are more anoxic areas with lower grazing pressure on the sea floor. Consequently, hypoxia associated with coastal eutrophication could be contributing to increased incidence and severity of harmful algal blooms by releasing cysts from grazing pressure in anoxic benthic habitats.

ACKNOWLEDGEMENTS

We are very grateful to Anke Kremp (at Woods Hole Oceanographic Institution in 2002) for providing the *Scrippsiella lachrymosa* B10 strain, along with culturing and encystment advice, to Jennifer Alix at Milford Laboratory for assistance and maintaining the culture, and to Hanna and Gunnar Persson for collecting snails for the experiment. This research was performed while Dr. Agneta Persson held a National Research Council Research Associateship Award at the National Oceanic and Atmospheric Administration, National Marine Fisheries Service Laboratory in Milford, Connecticut. Mention of trade names does not imply endorsement.

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Revised ms. accepted 15 March 2007